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CONTENT

Anisimov Dmytro
MODELS OF COUNTERING CRIME IN SPORT: FOREIGN EXPERIENCE AND PROSPECTS FOR UKRAINE 6
Atamanchuk Maryna, Pecheriaha Svitlana
GENETIC SCREENING IN PREGNANT WOMEN: NON-INVASIVE PRENATAL TESTING 21
Borysenko Nadiia
THE EDUCATIONAL POTENTIAL OF CONTEMPORARY DECORATIVE ART IN THE PROFESSIONAL TRAINING OF FUTURE TECHNOLOGY TEACHERS 35
Datsii Nadiia, Chepel Anna
COMMUNICATION CONTINUITY UNDER INFRASTRUCTURE DISRUPTION: AN INCLUSIVE LOCAL GOVERNMENT PROTOCOL FOR UKRAINE 49
Honcharov Denys
THE IMPACT OF THE ORDER OF PRESENTING SAMPLES FROM DIFFERENT DIAGNOSTIC CLASSES ON THE TRAINING AND EVALUATION OF CLASSIFIERS 67
Isaieva Inna, Karmazina Iryna
DIETARY PATTERNS AND THEIR ROLE IN CENTRAL NERVOUS SYSTEM FUNCTIONING 79
Krisilov Viktor, Komlevoi Oleksandr, Chesnokova Maryna
METHODS OF INTELLIGENT DATA ANALYSIS IN BIOLOGICAL RESEARCH 92
Мегем Олеся, Міщенко Сергій, Кириєнко Олена
ТРАВМА-ІНФОРМОВАНА ПРОФІЛАКТИКА ХІМІЧНИХ АДИКЦІЙ ТА ПСИХОСОЦІАЛЬНА РЕАБІЛІТАЦІЯ НАСЕЛЕННЯ, ПОСТРАЖДАЛОГО ВІД ВІЙНИ: ЄВРОПЕЙСЬКІ ПРАКТИКИ ТА ПЕРСПЕКТИВИ МІЖДЕРЖАВНОЇ СПІВПРАЦІ 105
Melnychuk Yuliia, Arestovych Andrii
CONCEPTUAL APPROACHES TO DESIGNING AN INTERACTIVE ONLINE COURSE ON THE INTERNET OF THINGS FOR VOCATIONAL EDUCATION STUDENTS 122
Melnychuk Yuliia, Deineha Roman
VIRTUAL SIMULATION-BASED LEARNING AS A TOOL FOR PRACTICE-ORIENTED PROFESSIONAL TRAINING OF FUTURE SPECIALISTS 135

Isaieva Inna, PhD, Assoc. professor, Department of Physiology Kharkiv National Medical University, Kharkiv, Ukraine, https://orcid.org/0000-0003-2941-5587

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DIETARY PATTERNS AND THEIR ROLE IN CENTRAL NERVOUS SYSTEM FUNCTIONING

Abstract

Diet is one of the key modifiable components of lifestyle and plays an important role in metabolic health and the functional state of the central nervous system. This article provides a theoretical overview of current scientific evidence on the relationship between dietary patterns, brain functioning, stress resilience, and cognitive processes, with particular attention to the relevance of these interactions in young people. Nutrition is considered as a complex factor whose effects depend not only on individual nutrients but also on the overall structure and quality of the diet. The article discusses the main characteristics of a healthy dietary pattern: energy adequacy, macronutrient balance, dietary diversity, sufficient consumption of vegetables, fruits, legumes, whole grains, nuts, and other nutrient-dense foods, as well as moderation in the intake of free sugars, salt, saturated and trans fats, and ultra-processed foods. The physiological roles of proteins, fats, and carbohydrates in supporting nervous system function are outlined. Current research on dietary patterns, including the Mediterranean diet, and their associations with cognitive performance and cognitive decline is reviewed. Evidence linking high consumption of ultra-processed foods with less favourable cognitive outcomes is also considered, taking into account the limitations of observational studies and the heterogeneity of findings. The article further examines

the gut–brain axis as a bidirectional communication system involving neural, endocrine, immune, and metabolic pathways. Particular attention is paid to the role of diet in shaping gut microbiota composition and activity, including the fermentation of dietary fibre and the production of short-chain fatty acids, which may contribute to intestinal barrier function, immune regulation, and gut–brain signalling. Evidence concerning associations among gut microbiota, psychological stress, stress resilience, and cognitive functions is discussed, while acknowledging that causal relationships have not yet been conclusively established.

The reviewed findings support the consideration of dietary quality and eating behaviour as important modifiable factors in research on stress resilience and cognitive functioning. A comprehensive assessment of dietary patterns may provide a basis for investigating the interaction of nutritional, metabolic, and neurophysiological factors in young people.

Keywords: diet, dietary patterns, diet quality, gut–brain axis, gut microbiota.

Diet is one of the principal modifiable lifestyle factors influencing metabolic health and the functional state of the central nervous system. Adequate energy and nutrient intake is essential for maintaining neuronal activity, neurotransmitter synthesis, synaptic transmission, and other physiological processes underlying cognitive functioning and adaptation to stress. Contemporary dietary patterns are characterised by substantial variation in nutritional quality, dietary diversity, and the consumption of minimally processed and ultra-processed foods. These differences may affect metabolic regulation, neurophysiological processes, and mechanisms involved in the stress response. However, the relationship between nutrition, cognitive functions, and stress resilience is complex and cannot be explained solely by the intake of individual nutrients.

Although increasing scientific attention has been directed towards the effects of dietary patterns on brain health, much of the available evidence concerns middle-aged

and older adults. The relationships between dietary quality, stress resilience, and cognitive functioning in healthy young people remain less extensively investigated. Therefore, a comprehensive assessment of dietary patterns, including energy adequacy, macronutrient balance, dietary diversity, food quality, and eating behaviour, is necessary to better understand the potential role of nutrition in maintaining cognitive functioning and physiological adaptation to stress in young people.

The aim of this article is to analyse and synthesise current scientific evidence on diet as a modifiable lifestyle factor associated with central nervous system functioning, cognitive processes, and stress resilience, with particular attention to dietary quality, nutritional patterns, and the potential role of the microbiota–gut–brain axis in young people.

Diet is one of the principal modifiable components of lifestyle, supplying the body with energy and nutrients necessary to maintain its structural and functional integrity. Adequate nutrition is particularly important for the central nervous system, whose functioning is characterized by high energy requirements and depends on a continuous supply of glucose, amino acids, fatty acids, vitamins, minerals, and other biologically active compounds. Dietary patterns should therefore be considered not only a determinant of metabolic health but also a factor that helps establish the conditions required for normal brain function.

Current understanding of the relationship between diet and nervous system function extends beyond the assessment of individual nutrients. The overall structure of the diet, combinations of foods, nutritional value, regularity of consumption, and proportions of major components are also important. Consequently, contemporary research increasingly evaluates whole dietary patterns rather than isolated foods or nutrients. A systematic review of neuroimaging studies found that healthy dietary and nutrient patterns were associated with measures potentially indicating a more favorable functional state of the brain, whereas less healthy dietary patterns were associated with less favorable measures of brain volume and cognitive functioning [1].

Diet is also closely related to the body's metabolic state, which in turn is important for central nervous system function. Excessive consumption of energy-dense foods with low nutritional value may contribute to metabolic disturbances. By contrast, a diet containing sufficient vegetables, fruit, legumes, whole grains, nuts, fish, and other nutrient-rich foods provides a broad range of essential nutrients and bioactive compounds. This principle underlies most contemporary approaches to healthy eating. An important characteristic of a diet is its energy adequacy. Both insufficient and excessive energy intake may adversely affect the body's functional state. A stable supply of energy is particularly important for the nervous system because the brain requires a continuous supply of energy substrates to maintain membrane potentials, synaptic transmission, neurotransmitter processes, and other functions. Dietary assessment should therefore consider not only food quality but also whether the energy content of the diet meets the body's needs.

The balance and quality of macronutrients are equally important. Proteins provide amino acids required for the synthesis of structural components of nervous tissue, enzymes, and neurotransmitters. Fats form part of cell membranes and contribute to nervous system function; polyunsaturated fatty acids are particularly important. Carbohydrates are an important source of energy for the brain. However, the physiological significance of macronutrients depends not only on their quantity but also on the quality of the foods from which they are obtained. In this context, the balance between minimally processed and ultra-processed foods deserves particular attention. Current research indicates unfavorable associations between high ultra-processed food intake and measures of cognitive health, although most available studies are observational and cannot establish causality conclusively. A 2024 systematic review found that a higher proportion of ultra-processed foods in the diet was generally associated with less favorable cognitive outcomes in studies examining their relationship with cognitive health [2]. Importantly, potential benefits are associated not with a single food but with the overall quality of the dietary pattern. A

systematic review of prospective and intervention studies found that healthy dietary patterns, including the Mediterranean diet, were associated with better cognitive functioning and a lower risk of cognitive decline in a substantial proportion of studies. However, findings were not consistent across all studies, highlighting the complexity of the relationship between diet and cognitive functions and the need for further research [3]. The importance of dietary patterns for cognitive functioning is also supported by systematic reviews of randomized controlled trials. An analysis of 61 studies found that dietary interventions, individual foods, and dietary supplements were associated in some studies with improvements in certain cognitive measures or measures of brain-tissue integrity. The most promising findings were reported for the Mediterranean dietary pattern, although the overall evidence base was substantially heterogeneous [4]. Diet may therefore be viewed as a complex modifiable factor that potentially affects central nervous system functioning through a combination of metabolic, neurophysiological, and other mechanisms. Assessing its effects requires consideration not only of individual nutrients but also of overall diet quality, dietary-pattern structure, the proportions of major food groups, and eating behavior. This issue is particularly relevant when studying young people. Long-term eating patterns are formed and consolidated during youth and may subsequently influence metabolic and cognitive health. However, most studies investigating the relationship between diet and cognitive functions have involved middle-aged and older adults, while evidence concerning healthy young people is less extensive. This supports the need to investigate dietary patterns and eating behavior in young people in the context of their functional and psychophysiological state. Accordingly, dietary assessment should include a comprehensive characterization of the diet, including energy adequacy; the qualitative and quantitative composition of macronutrients; consumption of major food groups; the proportion of foods with high and low nutritional value; and features of eating behavior. This approach moves beyond the assessment of individual foods

towards characterizing a person's actual dietary pattern and provides a basis for further analysis of its relationship with stress resilience and cognitive functions.

Diet Quality and Overall Dietary Patterns

Diet quality is a key indicator of how well a diet meets the body's physiological needs. Unlike the assessment of a single food or nutrient, diet quality involves a comprehensive evaluation of dietary diversity, energy and nutrient adequacy, the balance of major macronutrients, the frequency of consumption of different food groups, and the amount of foods or dietary components whose excessive consumption may adversely affect health. Contemporary approaches to healthy-diet assessment are based on this comprehensive evaluation rather than on isolated analysis of individual dietary components. The World Health Organization identifies four basic characteristics of a healthy diet: adequacy, balance, moderation, and diversity. Adequacy means providing sufficient energy and essential macro- and micronutrients without deficiency or excess. Balance refers to matching energy intake with energy expenditure and maintaining appropriate proportions of protein, fat, and carbohydrate. Moderation involves limiting dietary components whose excessive consumption may harm health. Diversity means including a broad range of nutritious foods from different food groups [5]. Energy adequacy is an important component of a nutritionally complete diet. Energy intake should meet individual requirements, which depend on age, sex, physical activity, metabolic characteristics, and other factors. A prolonged imbalance between energy intake and expenditure may result in either inadequate energy supply or excessive energy storage. Dietary assessment should therefore consider not only food quality but also whether the diet's energy content meets the needs of the individual [5]. Another important aspect of diet quality is the balance of the major macronutrients: protein, fat, and carbohydrate. Proteins supply amino acids required for the synthesis of cellular structural components, enzymes, and biologically active compounds. Fats are a concentrated source of energy, form part of cell membranes, and provide essential fatty acids. Carbohydrates are a major energy source

and should be obtained primarily from foods rich in dietary fiber, including whole grains, vegetables, fruit, and legumes. The quality of the foods supplying these macronutrients is as important as their relative quantities [5]. A healthy diet is characterized by a variety of nutrient-dense foods. These include vegetables and fruit, legumes, nuts, seeds, whole grains, and adequate sources of protein from animal or plant origins. Dietary diversity increases the likelihood of obtaining sufficient vitamins and minerals while reducing dependence on a narrow range of foods [5, 6]. Vegetables and fruit are particularly important sources of vitamins, minerals, dietary fiber, and diverse bioactive plant compounds. The WHO recommends that adults and children older than 10 years consume at least 400 g of vegetables and fruit per day. Variety is important because different plant foods contain different combinations of nutrients and bioactive compounds [5]. Legumes and whole-grain foods are also important components of a healthy diet. They provide complex carbohydrates, dietary fibre, plant protein, vitamins, and minerals. The WHO recommends that most carbohydrates come from unrefined sources, including whole grains, vegetables, fruit, and legumes. For adults, an intake of at least 25 g of naturally occurring dietary fiber per day is recommended [5]. The quality of fats is another important characteristic of a healthy diet. Fats are necessary for normal cellular and nervous system function, but their physiological effects depend on their fatty-acid composition. The WHO recommends prioritizing unsaturated fatty acids, found in foods such as fish, nuts, avocados, and vegetable oils, while limiting saturated fat intake. Minimizing industrially produced trans fats is particularly important because they are not a necessary component of a healthy diet [5, 6]. Another important dietary consideration is limiting free sugars, excess salt, and foods high in saturated and trans fats. The WHO recommends that free sugars account for less than 10% of total daily energy intake and that salt intake remain below 5 g per day. These recommendations are primarily intended to help prevent noncommunicable diseases and maintain metabolic health [5, 6]. The degree of industrial food processing also deserves attention. Modern food systems are

characterized by the widespread availability of ultra-processed foods, which often contain substantial amounts of free sugars, salt, and saturated fats and have high energy density but relatively low levels of dietary fiber and other nutrients. The WHO identifies increasing consumption of highly processed foods and insufficient intake of fruit, vegetables, and dietary fiber as characteristic trends in contemporary dietary patterns [5]. Nevertheless, diet quality cannot be assessed solely by the presence or absence of individual foods labelled as “healthy” or “unhealthy.” Healthy eating is a comprehensive characteristic shaped by the sum of everyday food choices. For example, including vegetables in the diet does not fully offset excessive consumption of foods high in free sugars, salt, or saturated fats. Similarly, eliminating a single food without establishing a varied and adequate diet does not, by itself, ensure nutritional completeness. This approach is particularly important when investigating the relationship between diet and the functional state of the nervous system. The brain requires a continuous supply of energy and a broad range of nutrients. Consequently, deficiencies in individual components and poor overall diet quality may create unfavorable conditions for normal brain function. At the same time, current evidence indicates that the relationship between diet and cognitive functions is multifactorial and cannot be reduced to the effects of a single nutrient or food. Diet quality should therefore be viewed as a comprehensive characteristic encompassing energy adequacy, macronutrient balance, dietary diversity, sufficient consumption of vegetables, fruit, legumes, whole grains, and other nutrient-dense foods, as well as limits on free sugars, salt, saturated and trans fats, and excessive consumption of ultra-processed foods. This comprehensive approach is necessary for further assessment of dietary patterns and their possible relationship with stress resilience and cognitive functions in young people.

Diet, the Gut Microbiota, and the Gut–Brain Axis

In contemporary models of the relationship between diet and central nervous system functioning, the gut–brain axis is receiving increasing attention. It is a complex,

bidirectional communication system between the gastrointestinal tract and the central nervous system. Neural, endocrine, immune, and metabolic mechanisms are involved, and the gut microbiota is an important component of this interaction. The composition and functional activity of intestinal microorganisms may influence signals transmitted to the brain, while the functional state of the nervous system and the stress response may, in turn, alter gastrointestinal function and the gut microbiota [7, 8]. The defining feature of this system is its bidirectional nature. The gut microbiota is not an isolated component of the gastrointestinal tract; it contributes to the regulation of metabolic and immune processes, the production of biologically active metabolites, and the functioning of the intestinal barrier. Through several signalling pathways, these processes may affect the central nervous system. Conversely, stress responses and changes in central nervous system functioning may alter intestinal motility, intestinal-barrier permeability, and the conditions in which microorganisms live [7, 8].

Diet is an important modifiable factor that determines the composition and functional activity of the gut microbiota. Dietary patterns affect the availability of substrates for microorganisms, their metabolic activity, and the relative abundance of microbial populations. In this context, the amount and type of dietary fiber, the diversity of plant foods, the proportion of fermented foods, and the overall structure of the diet are particularly important. A contemporary review of the interactions among diet, the microbiota, and the brain highlights diet as one of the most important factors capable of modifying the gut microbiota and the signals associated with it that reach the central nervous system [7]. One possible mechanism underlying this interaction is the metabolic activity of the gut microbiota. During the fermentation of dietary fiber, microorganisms produce short-chain fatty acids, including acetate, propionate, and butyrate. These metabolites may affect intestinal-barrier function, immune responses, and metabolic processes, and may also participate in signaling mechanisms that facilitate communication between the gut and the brain [7, 8]. Communication between the microbiota and the brain is not limited to metabolites. It also involves neuronal and

neuroendocrine mechanisms, including signals associated with the vagus nerve, as well as immune mediators and systems regulating the stress response. This multilevel interaction supports the view of the gut microbiota as one component of a complex regulatory system that may influence emotional state, behavior, and cognitive processes [7, 8]. The possible relationship between the gut microbiota, stress responses, and stress resilience is of considerable interest. A systematic review of human studies found that psychological stress may be associated with changes in gut microbiota composition. However, findings across studies were heterogeneous, and the small number of participants and predominantly observational nature of the research mean that a causal relationship between stress and microbiota changes cannot yet be established [9]. Importantly, the relationship between the microbiota and stress resilience may be bidirectional. A 2024 study examining interactions among the brain, gut, and microbiome found that microbiota characteristics were associated with individual differences in stress resilience and psychological well-being. These findings support the brain–gut–microbiome interaction model, but do not justify treating specific microbial characteristics as independent determinants of stress resilience [10]. Another area of research concerns the relationship between the microbiota and cognitive functions. A systematic review of studies involving healthy young people concluded that available evidence linking microbiota composition with cognitive measures and stress responses is promising but remains insufficient to establish the nature and direction of the relationship conclusively. The authors emphasized the need for higher-quality studies using standardized assessments of the microbiota, cognitive functions, and stress responses [11]. Diet may therefore affect the functioning of the gut–brain axis not only directly, through nutrient intake, but also indirectly, by modifying the gut microbiota and its metabolic activity. This creates a potential link between dietary patterns, intestinal health, regulation of the stress response, and cognitive functioning. Nevertheless, current evidence does not yet establish this mechanism as a definitive causal pathway, particularly in healthy young people.

Thus, including the quality and structure of diet in the assessment of factors associated with stress resilience and cognitive functions has a physiological as well as a behavioral rationale. Studying diet in the context of the gut–brain axis makes it possible to consider dietary patterns as a complex factor that may influence interconnected metabolic, immune, neuroendocrine, and neuronal mechanisms of adaptation.

Conclusions

1. Diet is an important modifiable lifestyle factor that contributes to metabolic regulation and provides the energy and nutrients required for normal central nervous system functioning.

2. The physiological significance of nutrition depends not only on individual nutrients but also on overall dietary quality, including energy adequacy, macronutrient balance, dietary diversity, and the consumption of nutrient-dense foods.

3. Available scientific evidence suggests associations between healthy dietary patterns, particularly the Mediterranean diet, and more favourable cognitive outcomes. However, the heterogeneity of existing studies and the predominance of observational evidence limit definitive causal conclusions.

4. The gut microbiota represents a potential link between dietary patterns, stress responses, and cognitive functioning through interconnected metabolic, immune, endocrine, and neural mechanisms. Nevertheless, the causal nature of these relationships remains insufficiently established.

5. Comprehensive dietary assessment is a promising approach for investigating the relationships between nutrition, stress resilience, and cognitive functions in young people. Further research involving standardised dietary, psychophysiological, and cognitive assessments is needed to clarify these associations.

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